Embrace Interference, Enable Scalability

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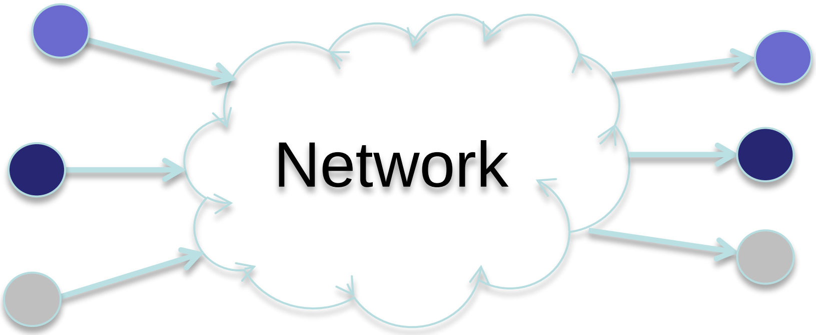
Question: How to Design The Network?



- Goals
  - Efficiency
  - Scalability
  - Robustness
- Impediment
  - Self Interference
  - Inter-User Interference
- Challenge : Define consolidated approach to jointly handle interference
  - How to rethink interference?
  - How to handle interference given network dynamics and limited information?

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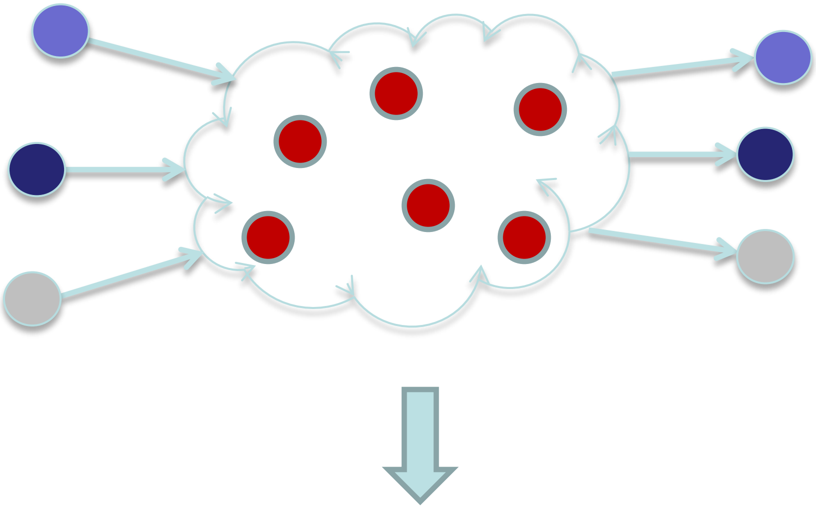
Current Solution: Intermediate Processing

- Relays recover and modify signals on each hop
  - Routing/collision-avoidance
  - Emulate co-operation (virtual MIMO)



- Perils of "Clever" Strategies
  - CSMA, TDMA, …
    ➔ Not robust to network dynamics
  - Virtual MIMO
    ➔ Not scalable
    ➔ Poor at Low SNRs

Antidote
"Dumb" Intermediate processing.
End-to-end resolution of interference.
Scalable without requiring scale

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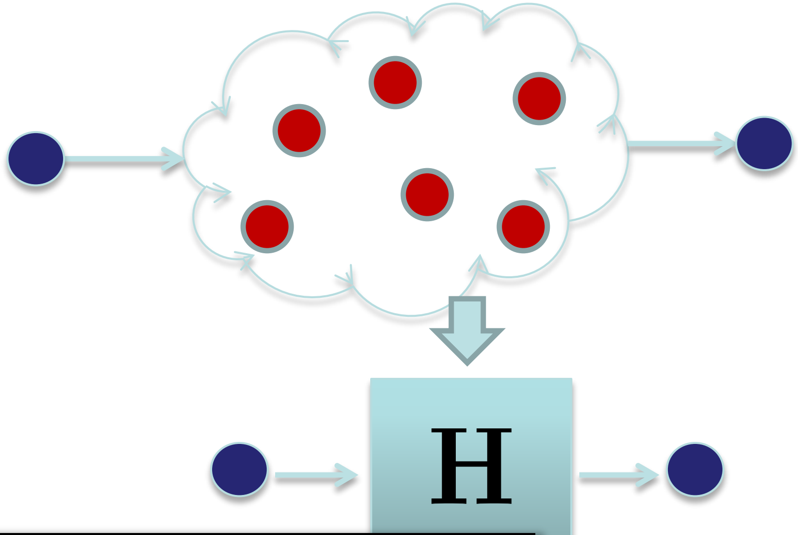
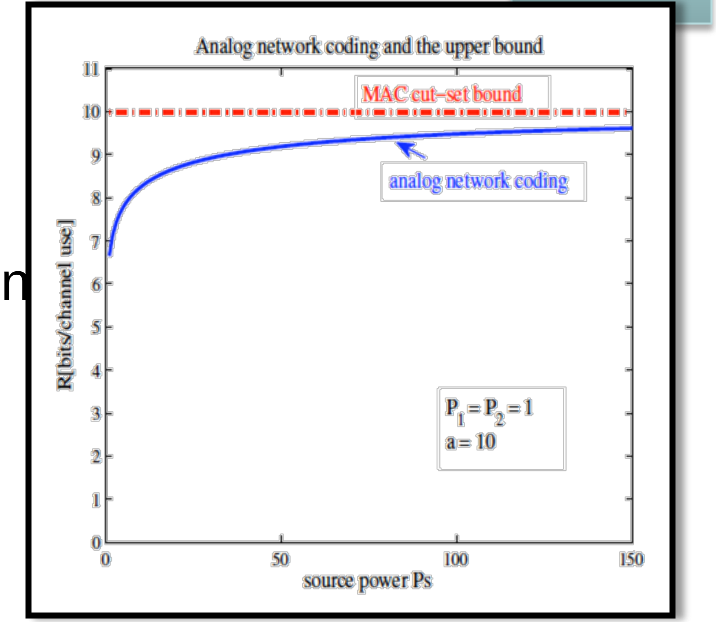
Example 1: Single Source and Destination

- Strategy
  - Amplify-and-forward in the network, ignorant of topology
  - Measure end-to-end channel matrix at the edges, H
  - Code at the edges per H
  - Analogous to random linear network coding



- Observations
  - Let SNR increase with input power
  - Close to optimal (information theoretic cut-set bound)



<u>Question</u>

How to expand model for multiple sources and destinations? (i.e. inter-user interference)

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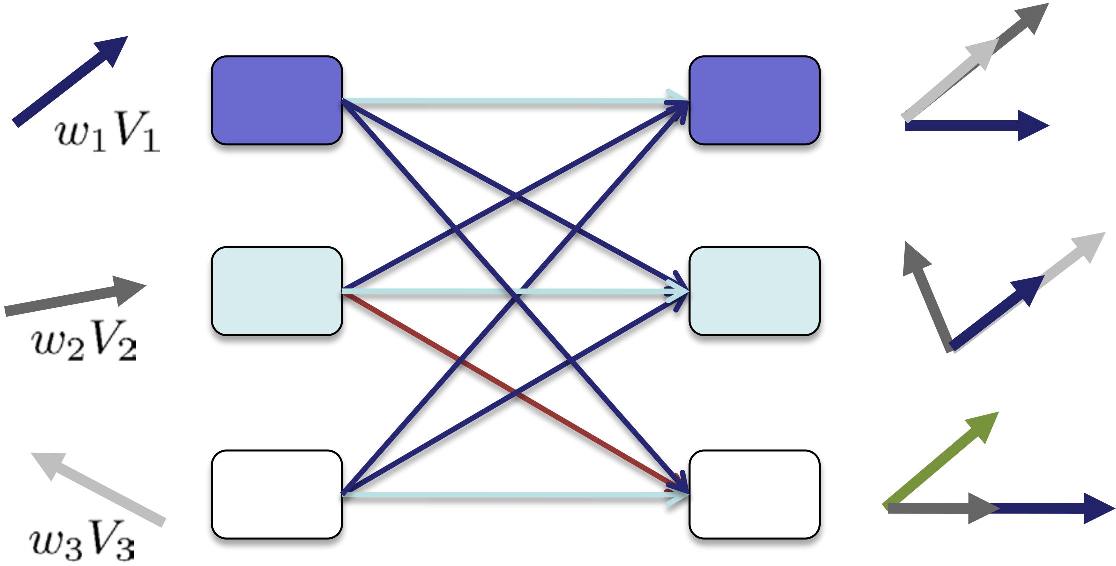
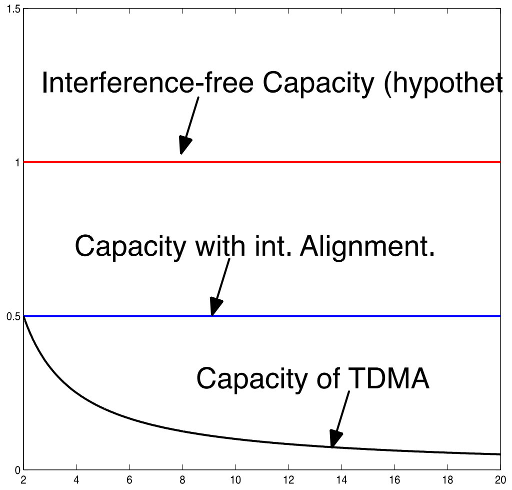
Starting Point: Interference Alignment

- ***Idea***
  Exploit inherent diversity in the network.

- ***Approach***
  – Each user gets one dimension in every two dimensions free of interference.



- ***Key Scalability Result***: In a system with K users,
  – With IA, Each user gets half the number of dimensions
  – With time-sharing, where each user gets a fraction of 1/K



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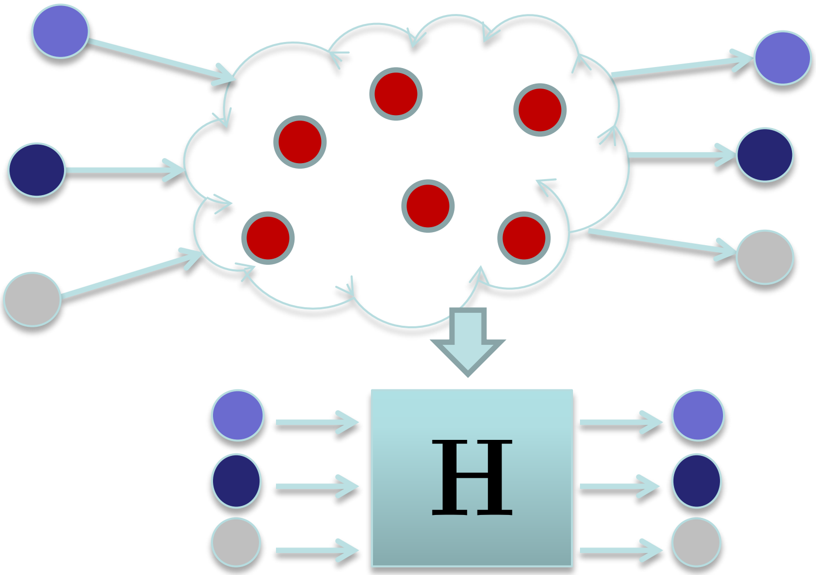
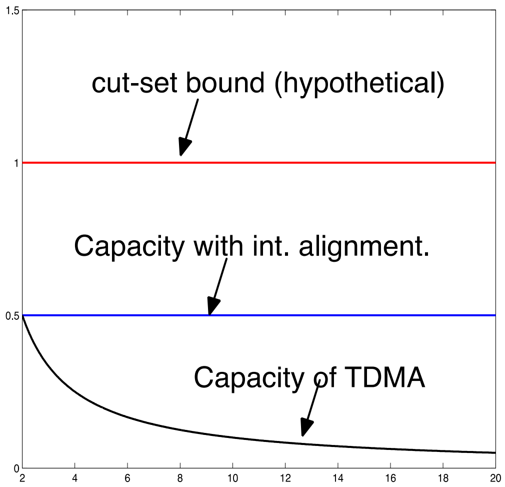
Example 2: Inter-User Interference

- Strategy
  - Random Coding
  - End-to-End Interference Alignment to Decouples Streams

- Questions
  - Can each user achieve half the min-cut = half the rank of H (subject to some conditions?)
  - Could potentially exploit knowledge of channel gain information, and/or topology information and/or asynchrony/delays in the network.



Can we show this?



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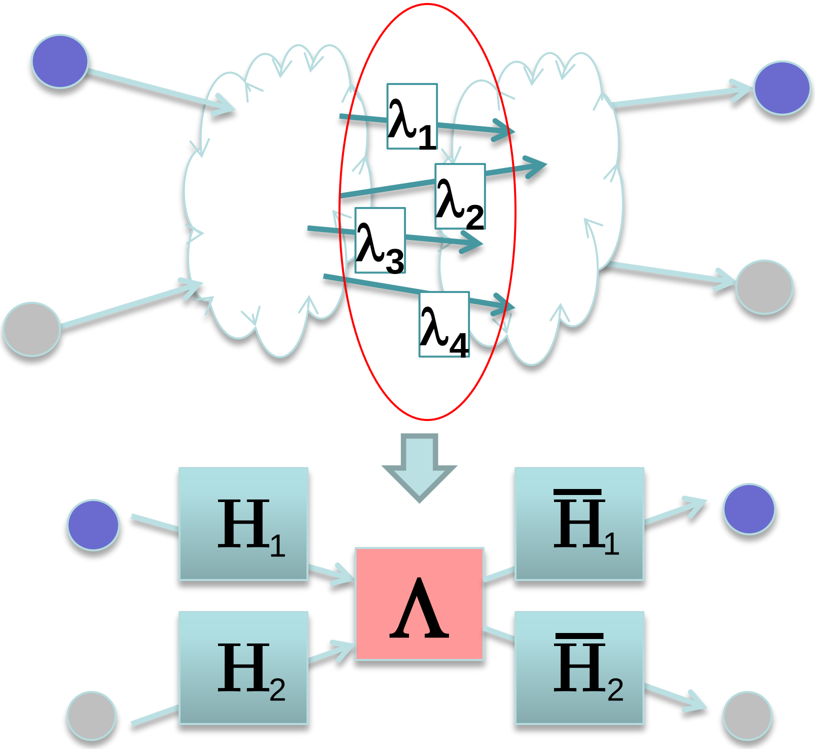
Example 3: Compatibility with Intermediate Processing

- Is the architecture compatible with intermediate processing?
  - Yes: Example from [Cadambe-Medard-Zeng 2013]
    - Perform processing at a few intermediate nodes
    - Random linear coding at all the other intermediate nodes



$$\mathbf{A}_1 = \mathbf{H}_1\mathbf{\Lambda}\overline{\mathbf{H}}_1, \quad \mathbf{A}_2 = \mathbf{H}_2\mathbf{\Lambda}\overline{\mathbf{H}}_1, \quad \mathbf{B}_2 = \mathbf{H}_2\mathbf{\Lambda}\overline{\mathbf{H}}_2$$

- Broader Principle
  - For efficiency, do processing all the static components (nodes).
  - For robustness, dumb processing at all dynamic components (nodes).

Key Idea:
Clever processing at a few nodes (Λ) to resolve interference.

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Summary

- Conclusions
  - “Embracing” Interference is necessary to achieve scalable networking in highly dynamic environments
  - Managing interference *end-to-end* and not hop-by-hop provides high throughput
  - Simplified intermediate processing is more robust to network dynamics

- Open Research Challenges
  - Theoretical capacity results for multi-hop networks
  - Results for large ranges of SNRs (promise of lattices coding)

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